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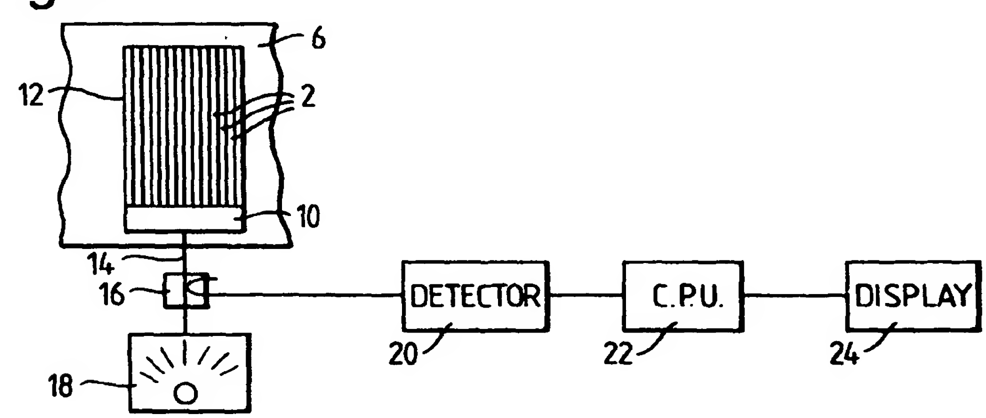
(54) Fibre optic damage detection system.

(57) A structural damage detection system for providing simultaneous monitoring of crack parameters utilising substantially parallel co-planer arrays (12) of fibre optic cables (2).

Fig.2.



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This invention relates to structural damage d - tection systems, and more particularly to structural damage det ction systems utilising optical fibres.

The use of surface mounted deformation and damage detection systems for the monitoring of structural integrity within metallic, ceramic or composite structures is well known within the construction and aerospace industries.

The monitoring of the structural integrity of any structure or "structural health" to which it is sometimes referred, consists of the measurement of a number of parameters usually including crack growth, crack direction and point strain measurement. In the field of fibre reinforced composites various techniques have been proposed for the measurement of crack and strain properties. These usually comprise of embedding the sensory device or fibre in the lay-up of the composite thus requiring detailed and specialist manufacturing techniques. In the field of metallic, ceramic and civil engineering construction, crack detection is usually conducted using "tell tales". Tell tales comprise thin sections of either glass, conductive wire or cotton which when fastened to the structure will break as a crack propagates between their fastened length. Tell tales give a visual indication of crack propagation or in the case of conductive wire can be arranged to give an electrical indication (i.e. breakage). Allied to the measurement of structural health strain measurement is usually conducted using metallic strain gauges bonded onto the surface of a structure. A recent advance in fibre optic technology was the use of "Bragg" gratings which are patterns laser etched onto a single glass fibre which perform a similar function to a conventional strain gauge but on a far reduced physical scale.

The monitoring of structural health therefore requires the combination of a number of techniques for different materials if it is to be conducted in situ i.e. from within or attached to the structure, as opposed to the traditional external non-destructive test techniques such as eddy current sensing or dye penetrant methods.

It is an object of the present invention to provide a structural damage detection system which may be employed with structures of any material required to be monitored.

It is another object of the present invention to provide a structural damage detection system which provides for the simultaneous monitoring of crack positioning, propagation rate, direction and point strain levels.

According to the present invention in one aspect thereof a method of measuring structural defects of a structure includes the steps of:

a) Attaching to said structure at least one structural defect sensor comprising a plurality of longitudinally xtending fibre optic cables mounted in a pred termined spaced apart substantially parallel co-planer array, one side of said array being adapted for attachm nt to a surface of a structur to be tested,

b) coupling each of said fibre optic cables to a light source, and,

c) monitoring a variation of a light parameter measured by said light.

According to the present invention in another aspect thereof there is provided a structural damage sensor comprising a plurality of longitudinally extending fibre optic cables mounted in a predetermined spaced apart substantially parallel co-planar array one side of said array being adapted for attachment to a surface of a structure to be tested.

An embodiment of the invention will now be explained by way of a non-limiting example in which the following figures will be referred to:

Figure 1A and 1B are cross sectional views of optical fibre ribbon cable assemblies mounted on structures to be tested,

Figure 2 is a block schematic diagram of apparatus used in a typical structural health monitoring scenario,

Figure 3 is a block schematic diagram of an alternative arrangement to that of Figure 2 for structural health monitoring.

Figure 4 is a plan view of a structure under test showing the effects of crack propagation on the optical fibre ribbon cable of Figure 1A or Figure 1B,

Figure 5 is a perspective view showing the layout of typical Bragg gratings along the ribbon cable, and

Figure 6 is a plan view showing a typical application of the apparatus according to the invention to aircraft structural health monitoring.

Referring to Figures 1A and 1B an array of co-planar parallel optical fibres 2 are bonded together and held in a matrix 8 which may be of either polymer or elastomeric composition. This arrangement of fibres is known as a "ribbon cable" which additionally can have some pre-impregnated adhesive surface incorporated on one side 4 to enable the cable to be bonded to a typical surface 6 shown here as metallic.

Figure 2 shows apparatus which may be used in an application for monitoring both crack properties and point strain measurements. A ribbon cable 12, comprising fibre optic cables 2 is bonded to the surface of a structure 6 using the adhesive pre-impregnated on the ribbon cable 12. The ribbon cable 12 is then fastened to an end connector 10 which combines the optical fibres 2 into a fibre bundle 14 which connects via an optical switch 16 to a light source 18.

The light from source 18 is directed along fibre bundle 14, through the optical switch 16 and into the ribbon end connector 10. The light is then passed along each individual optical fibre within which the light reflects internally either at its end position or at

a br ak point within the ribbon 12. The reflected light travels back through the connector 10 into the fibre bundle 14 and via th optical switch 14 to a detector unit 20. In the detector unit 20 the optical signals are converted to digital or analogue form before being sent to the CPU 22 for processing. Once processed the CPU 22 outputs the information obtained to a display means 24 comprising either video or printer or alternative display format.

Figure 3 shows an alternative arrangement to Figure 2 whereby a second light source 26, optical switching unit 30 and detector 34 are utilised in combination with the apparatus described in Figure 2. The reflection of light from both ends of a ribbon cable will result in two signals requiring processing by the CPU 22 and thus enables the positioning of any discontinuity on an individual fibre 2 to be more accurately established.

The detection system 20 and 34 will use an appropriate method for determining the distance of the fibre discontinuity from the light source or end connector reference position, such as time domain measurement, and a multiplexing system for determining from which fibre the light source is being analysed.

By way of an example of the inventions application to structural health monitoring, Figure 6 shows an optical fibre ribbon cable 12 positioned adjacent to a line of fasteners 36 in a typical aircraft structure.

Figure 4 shows the effect of crack propagation across the fibre direction of the ribbon cable and thus the damage to the fibres that will be detected by analysis.

Additionally, the fibres within the ribbon cable can be utilised to monitor point strain measurements by the inclusion of Bragg Gratings along the length of specific fibres.

Figure 5 shows one such grating 37 which when subjected to strain within the ribbon cable 12 will deform and thus produce a change in the reflected light characteristic of that fibre 2 which will be recognised by the detection system 20 and 34 as changes in strain levels.

Claims

1. A method of measuring structural defects of a structure including the steps of:

   a) Attaching to said structure at least one structural defect sensor each comprising a plurality of longitudinally extending fibre optic cables mounted in a predetermined spaced apart substantially parallel co-planer array, one side of said array being adapted for attachment to a surface of a structure to be tested,

   b) Coupling each of said fibre optic cables to a light source, and,

   c) monitoring a variation of a light parameter measured by said light

2. A structural defect sensor comprising a plurality of longitudinally extending fibre optic cables mounted in a predetermined spaced apart substantially parallel co-planar array one side of said array being adapted for attachment to a surface of a structure to be tested.

Fig.1.

Fig.2.

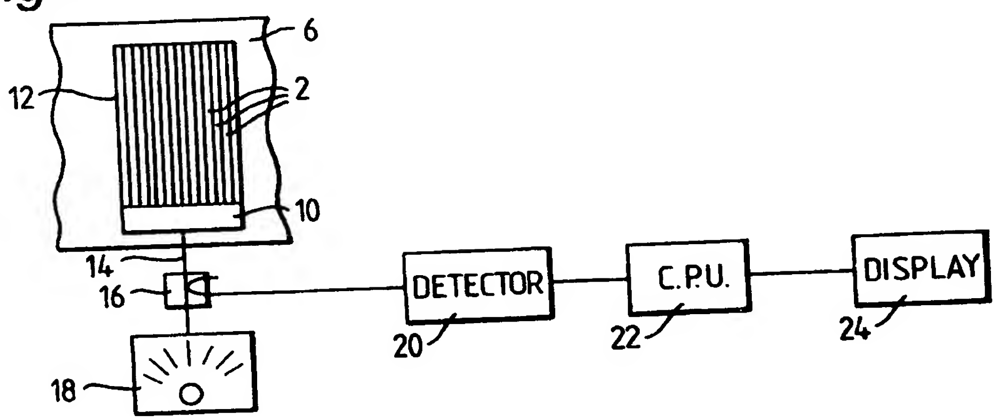


Fig.3.

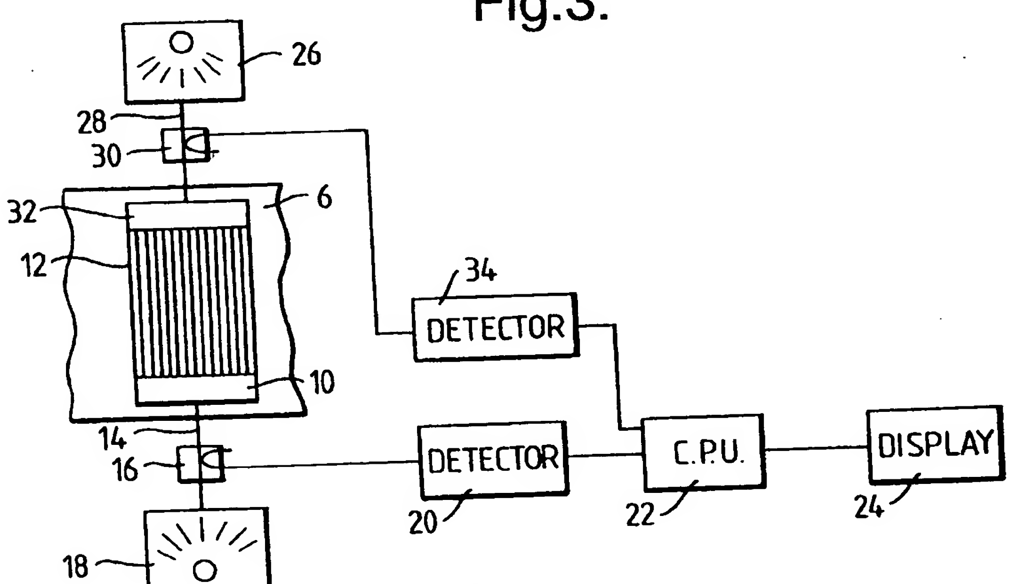


Fig.4.

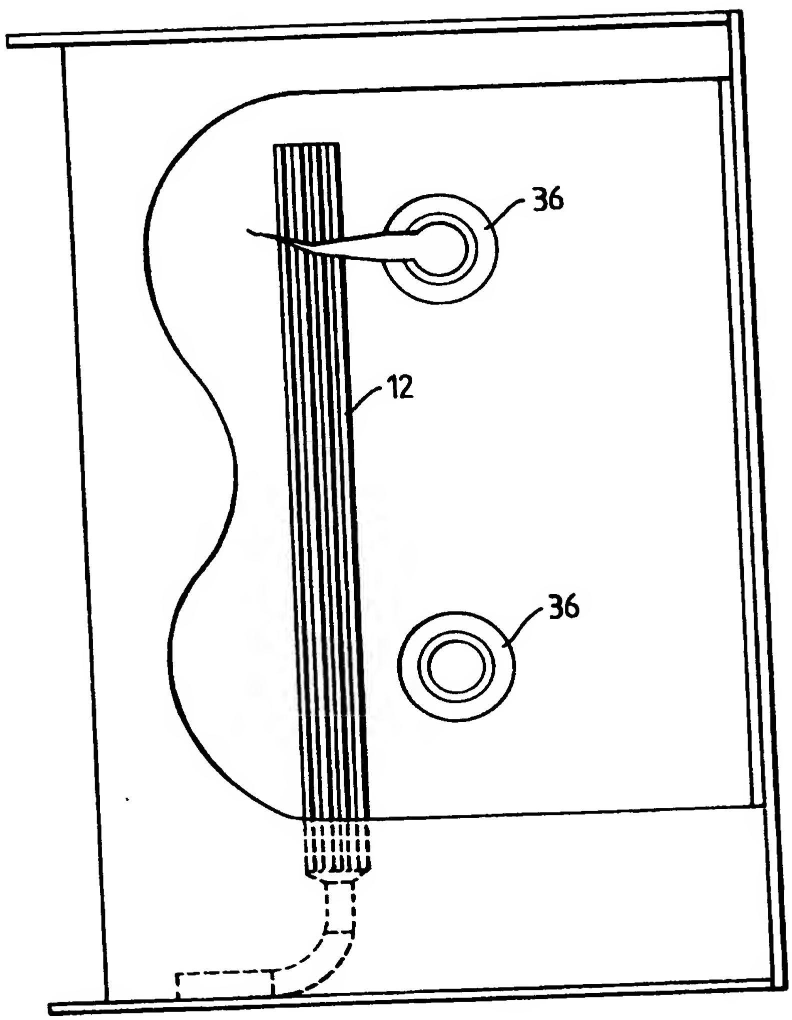


Fig.5.

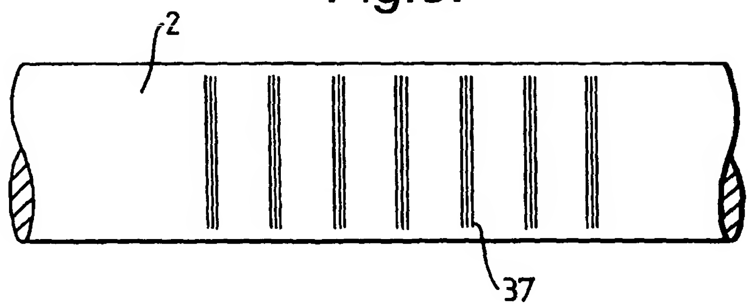
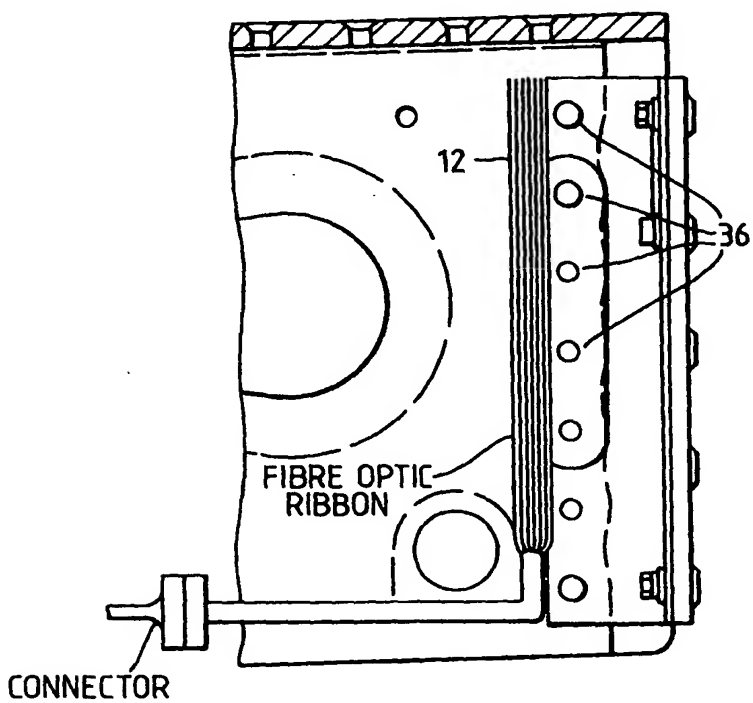


Fig.6.



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EUROPEAN SEARCH REPORT

Application Number
EP 94 30 6190

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE-A-31 42 392 (VEREINIGTE FLUGTECHNISCHE WERKE GMBH) * the whole document * ---	1,2	G01M11/08
X	DE-A-36 29 430 (MESSERSCHMITT-BÖLKOW-BLOHM GMBH) * the whole document * ---	1,2	
X	GB-A-2 145 515 (NMI LIMITED) * the whole document * ---	1,2	
X	GB-A-2 136 119 (NMI LIMITED) * the whole document * ---	1,2	
X	US-A-5 013 908 (J. CHANG) * the whole document * ---	1,2	
X	SMART MATERIALS & STRUCTURES, vol.1, no.1, March 1992, BRISTOL (GB) pages 36 - 44, XP000399871 R.M. MEASURES ET AL. 'WAVELENGTH DEMODULATED BRAGG GRATING FIBER OPTIC SENSING SYSTEMS FOR ADDRESSING SMART STRUCTURE CRITICAL ISSUES' * the whole document * -----	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G01M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 November 1994	Van Assche, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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